Weighing in on End Weight

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The Principle of End Weight

- "Phrases are presented in order of increasing weight." (Wasow 2002: 3; following Behagel 1909; Quirk et al. 1985)

  (1) peas and carrots > carrots and peas

  (2) the attitude of people who are really into classical music and feel that if it's not seventy-five years old, it hasn't stood the test of time >

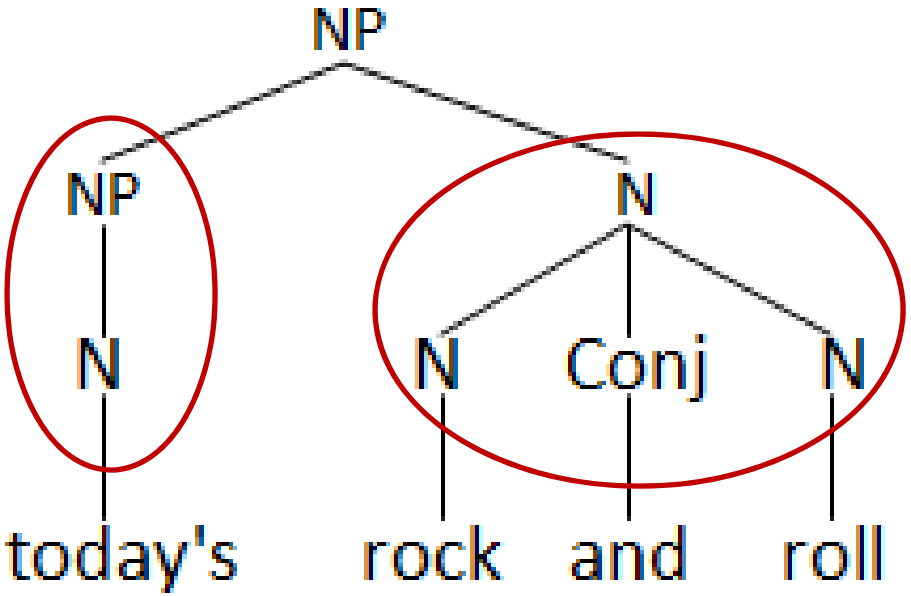
  people who are really into classical music and feel that if it's not seventy-five years old, it hasn't stood the test of time's attitude

- Facilitates planning, production, and parsing
- Cross-linguistic weight at peripheries

What is “weight”?

Syntax

- Syntactic complexity: heavy constituents are structurally more complex.
  - Number of syntactic nodes (e.g., Hawkins 1994)



What is "weight"?
Processing load

- Weight as structural integration cost: heavy constituents require more computational effort
  - Cost of relating an input into a projected structure depends on intervening computations
  - Dependency Locality Theory (Gibson 1998, 2000; Temperley 2007):
  - Each new referent (NP or finite verb) adds to integration cost

What is “weight”?
Phonology

- Phonological complexity: Heavy constituents have complex prosodic properties
  - Number of primary stressed syllables (Anttila et al. 2010; following Selkirk 1984; Zec and Inkelas 1990)

- Phonological weight:
  - Number of syllables (Benor and Levy 2006; McDonald et al. 1993; a.o.)

What is "weight"?

Word Count

- Many studies have used word count as proxy for other weight factors. (e.g., Wasow 2002; Szmrecsányi 2004; Bresnan and Ford 2010; a.o.)

- Correlated with many other measures

Which measure is appropriate?

- Most studies of syntactic alternations focus on syntactic/processing measures of weight
- Influence of phonological weight on syntax less understood
- Multiple weight measures rarely evaluated concurrently on the same data (cf., Szmrecsanyi 2004)

Present Study

The Data

- Two constructions in spoken American English
  (Switchboard Corpus, Godfrey & McDaniels 1992)

(1) Genitive Alternation

- *'s* -genitive ~ *of* genitive
- e.g., the car's wheel ~ the wheel of the car

(2) Dative Alternation

- double object construction ~ prepositional dative (*to*)
- e.g., give the dog the bone ~ give the bone to the dog

Present Study

Weight measures investigated

- Syntactic nodes
- Referents (discourse new)
- Words
- Syllables
- Primary stressed syllables

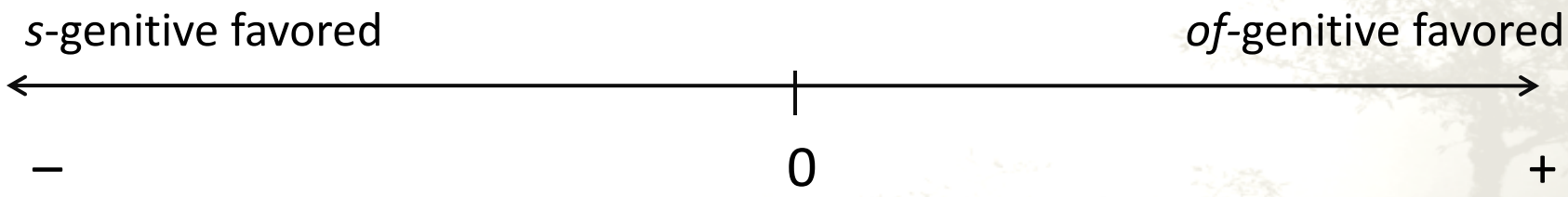
Present Study
Analyses

- Simple and mixed effects regression modeling (Shih et al. 2009; Shih et al. submitted; Hinrichs & Szmrecsányi 2007; Bresnan et al. 2007; Bresnan & Ford 2010; a.o.)
  - 5 individual models using each weight predictor
  - Controlled for other known variables influencing construction choice
  - Model comparison using Akaike Information Criterion (Burnham & Anderson 2004)
- Variable comparison using Random Forests analysis (Strobl et al. 2009b)
  - Single model containing all predictors

Genitives
Fixed Effects Model

- 663 *of*-genitives + 460 *s*-genitives = 1123 total
- Predictors: Possessor animacy, final sibilancy, rhythm (Shih et al. 2009; submitted)
- Comparative weight (Bresnan & Ford 2010)

Comparative weight = log(possessor weight) – log(possessum weight)



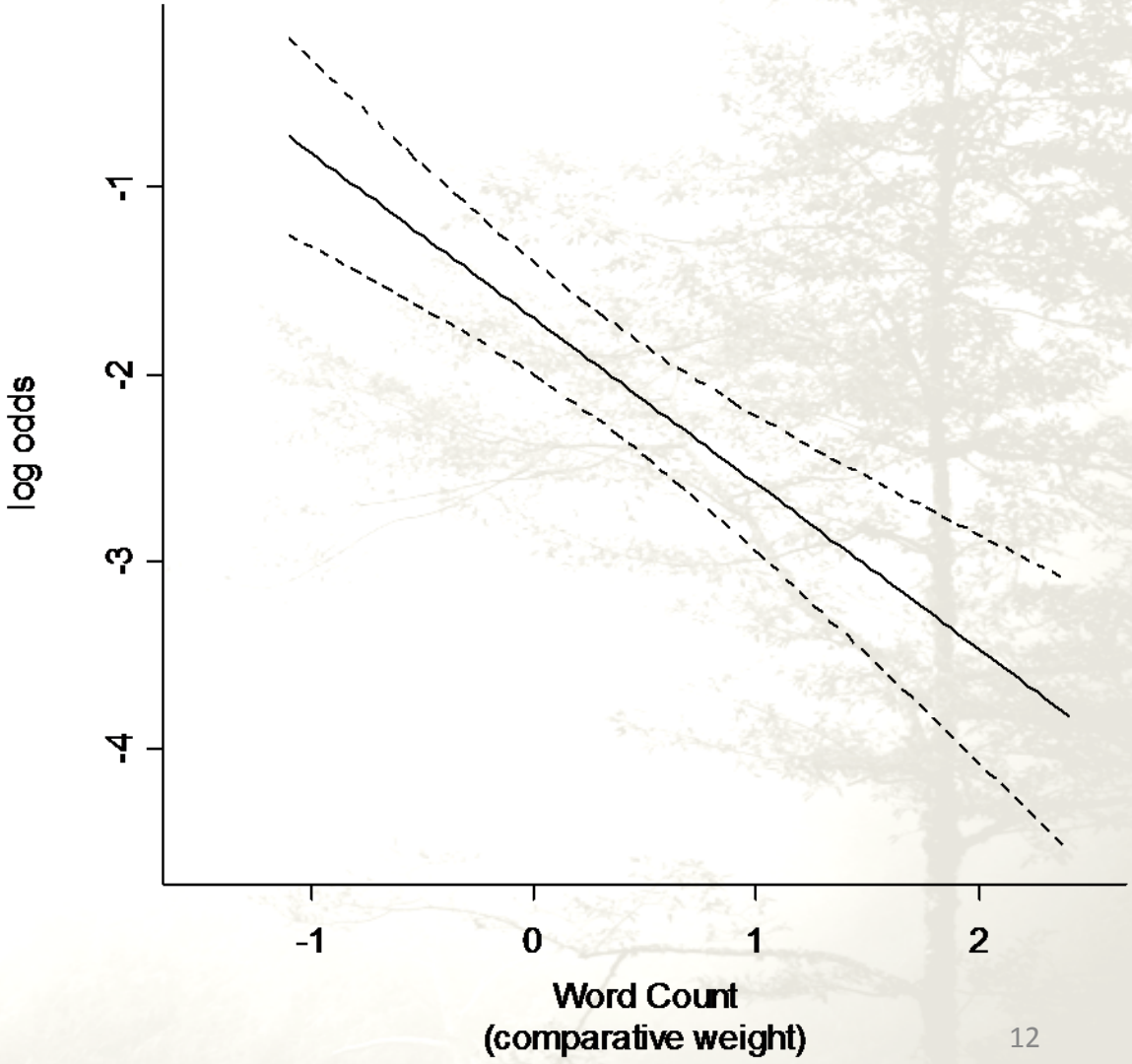
(*Referent counts were not log-transformed.)

Genitives: results

Heavy Possessors favor *of*-gen

- Higher log odds value = higher *s*-genitive likelihood
- Lower log odds value = higher *of*-genitive likelihood

➢ As the number of words in the possessor increases relative to the number of words in the possessum, an *of*-genitive becomes more likely.

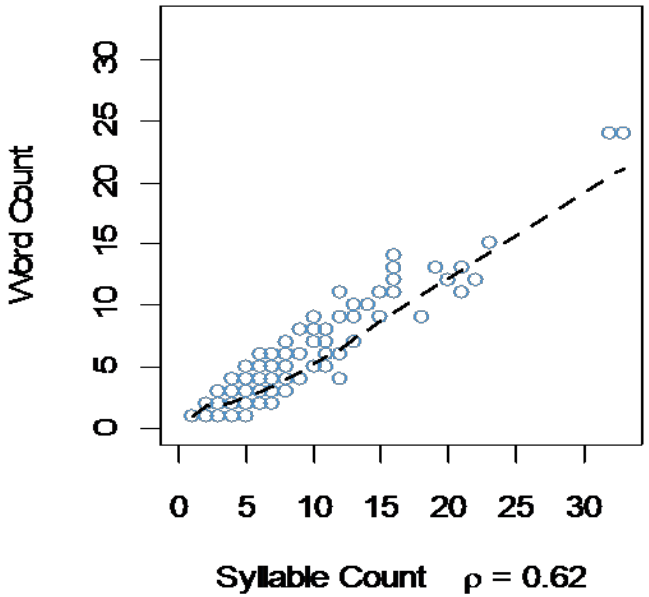


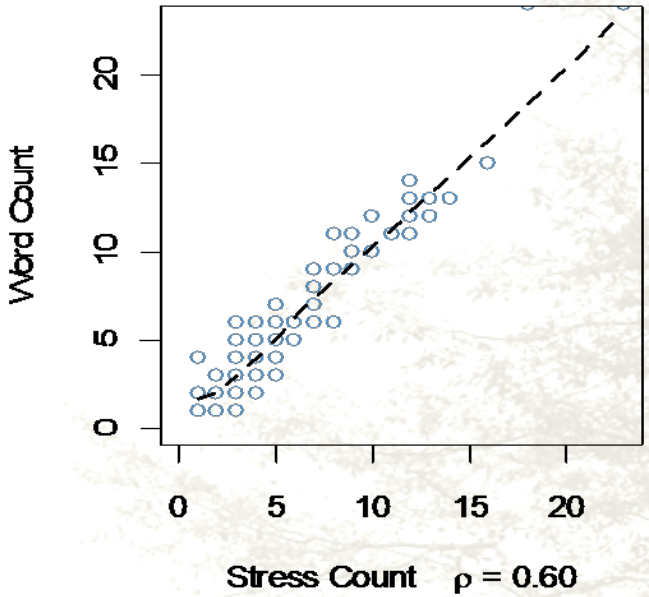
Genitives: results

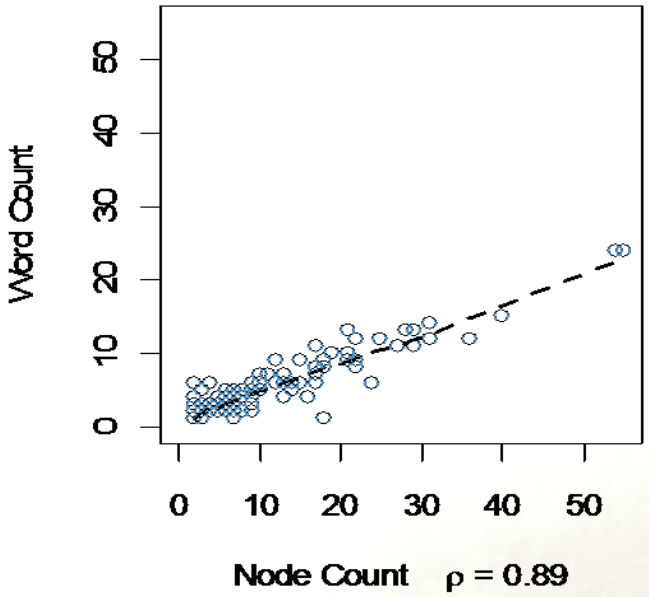
Individual Regression Analysis

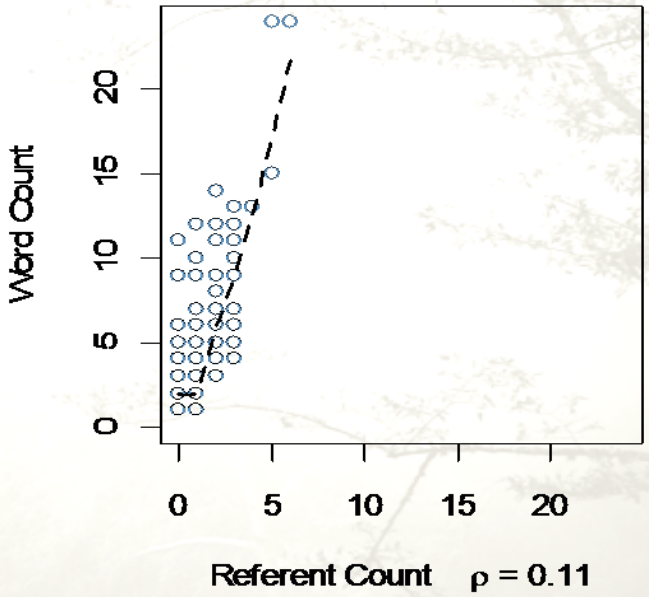
- Nodes
  - β = - 1. 234; z = -6.67; $p < 0.000$ (***)
- Words
  - β = - 0.884; z = -5.50; $p < 0.000$ (***)
- Referents
  - β = - 0.563; z = -3.71; $p < 0.001$ (**)
- Primary Stresses
  - β = - 0.525; z = -3.44; $p < 0. 001$ (**)
- Syllables
  - β = - 0.412; z = -3.42; $p < 0.001$ (**)

Genitives: results
High correlation of factors







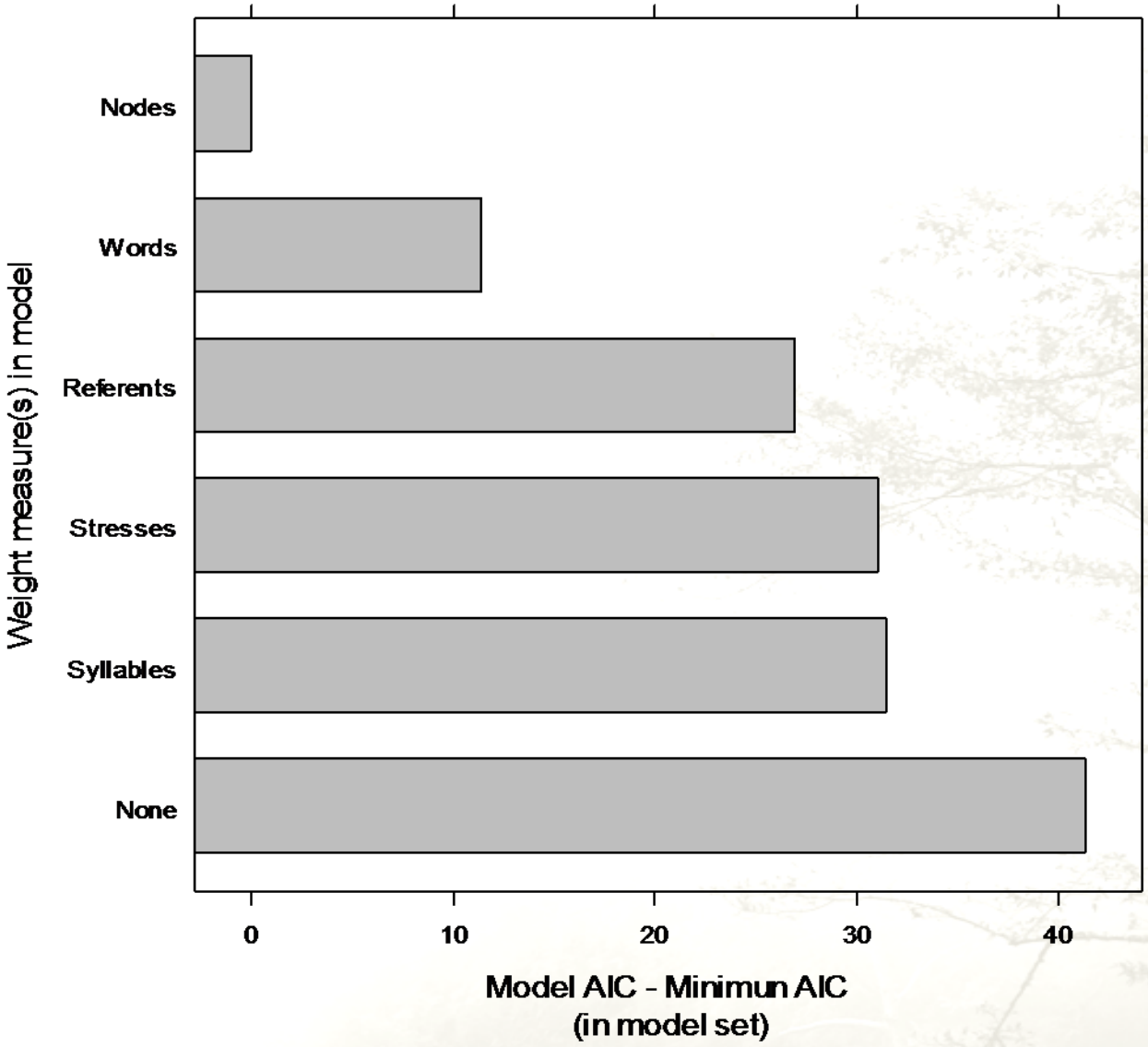


Genitives
Model AICs and factor weights

	Nodes**	Words	Referents	Stresses	Syllables	None
AIC	809.962	821.277	836.889	841.002	841.416	851.218
Δ ($AIC_m - AIC_{min}$)	0.00	11.315	26.927	31.04	31.454	41.256
w_m	0.997	0.003	0.00	0.00	0.00	0.00

- Models with $\Delta < 2$ have substantial support; $\Delta > 10$ have no support
- w_m = the probability that the model is the optimal one in the set (Burnham and Anderson 2006)

Genitives
Comparison of Models

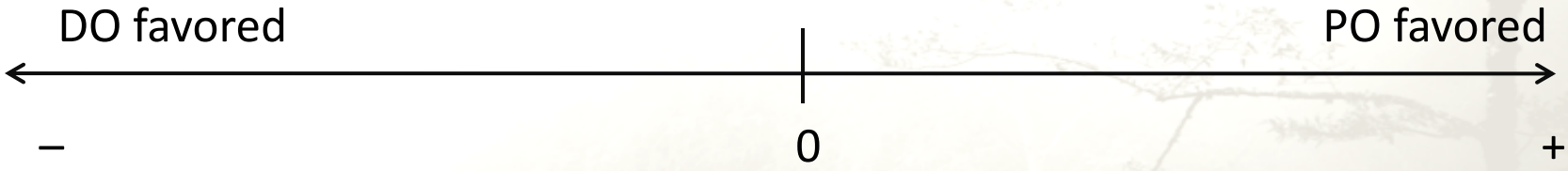


Datives
Mixed Effects Model

- 227 double objects + 183 prepositionals = 410 total

- Mixed effects model (Bresnan et al. 2007; Bresnan and Ford 2010)
  - Fixed effects: animacy of recipient, accessibility of recipient and theme, definiteness of recipient and theme
  - Random effects: Verb

Comparative weight = log(recipient weight) – log(theme weight)

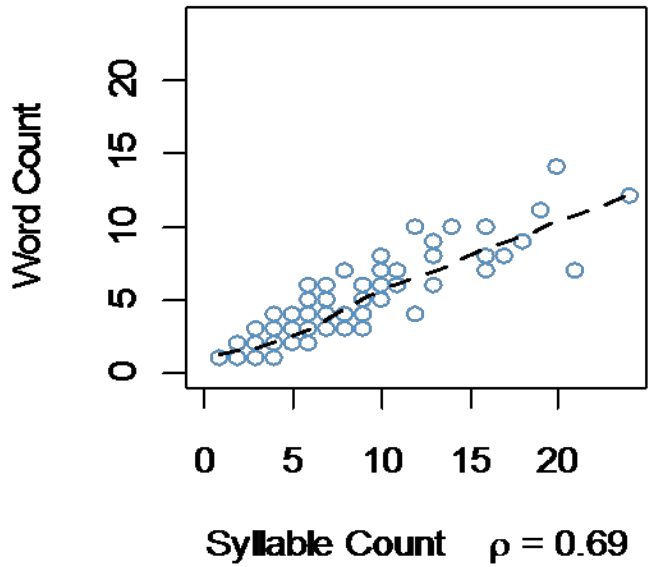


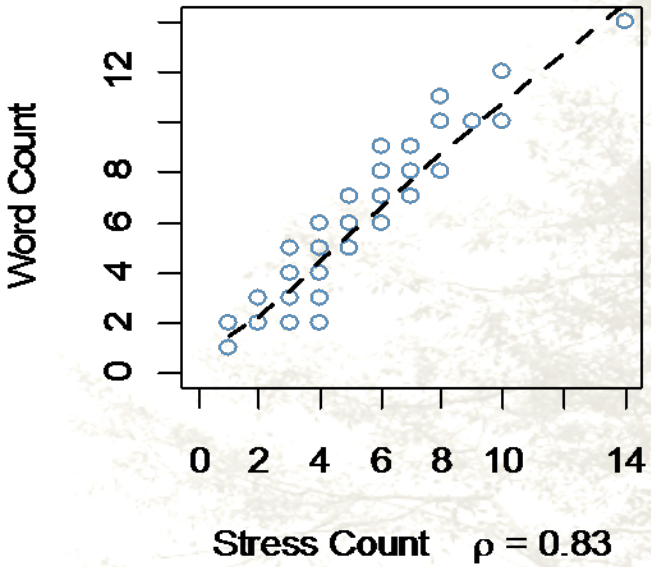
Datives: results

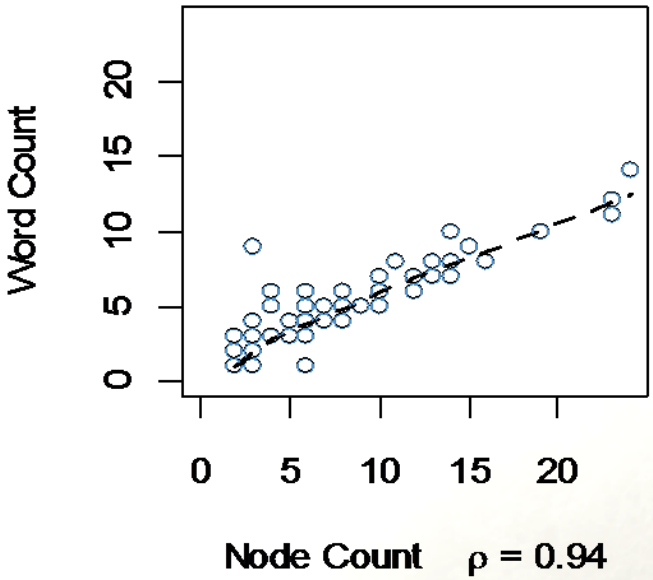
Individual Regression Analysis

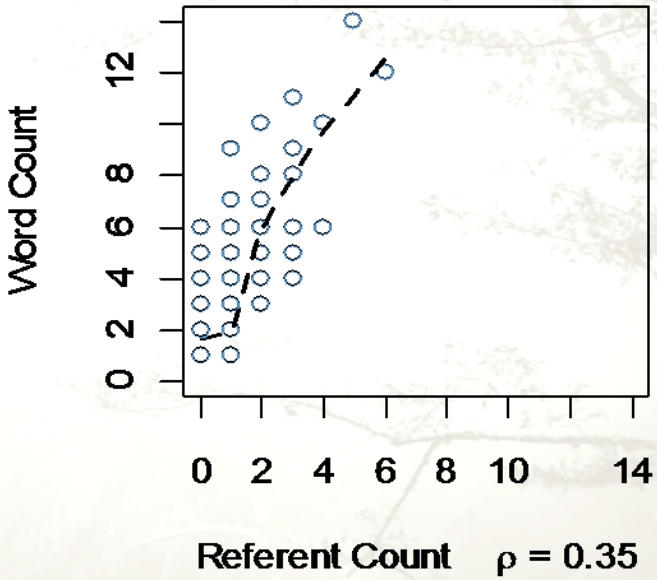
- Nodes
  - β = 1.312; z = 6.685; $p < 0.000$ (***)
- Words
  - β = 1.186; z = 6.877; $p < 0.000$ (***)
- Primary Stresses
  - β = 1.013; z = 6.304; $p < 0.000$ (***)
- Syllables
  - β = 1.040; z = 6.086; $p < 0.000$ (***)
- Referents
  - β = 0.207; z = 1.305; $p = .19$

Datives: results
High correlation of factors







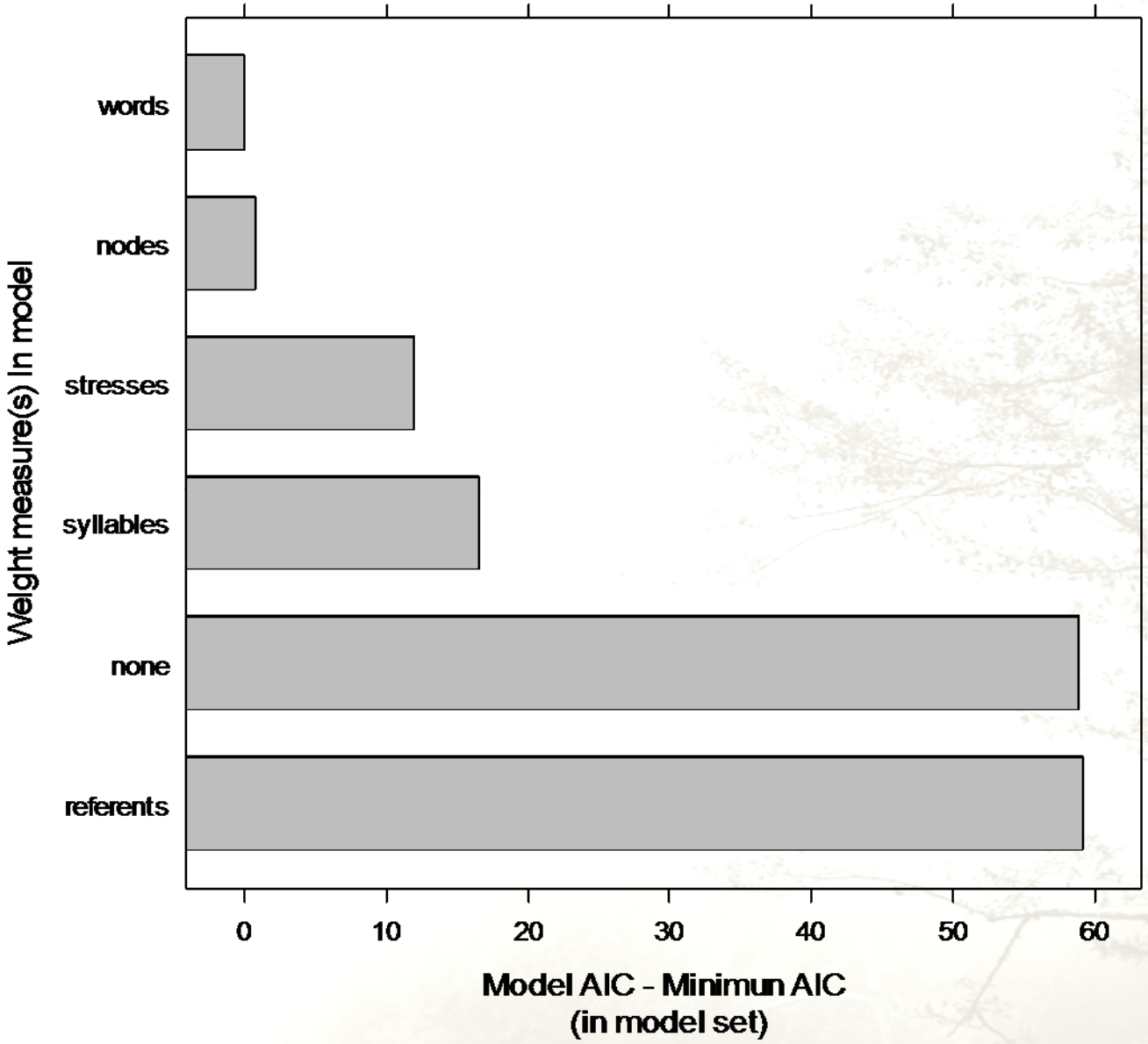


Datives
Model AICs and factor weights

	Words**	Nodes**	Stresses	Syllables	None	Referents
AIC	397.77	398.58	409.81	414.32	456.58	456.90
Δ ($AIC_m - AIC_{min}$)	0.00	0.81	12.04	16.55	58.81	59.13
w_m	0.60	0.40	0.00	0.00	0.00	0.00

- Models with $\Delta < 2$ have substantial support; $\Delta > 10$ have no support
- w_m = the probability that model is the optimal one in the set

Datives
Comparison of Models (AIC)



Random Forests

- Suited to datasets with complex interactions and highly correlated predictor variables (Strobl et al. 2008; 2009a; 2009b; a.o.)
- Recursive partitioning method:
  - Random subsamples of data, each fit with a single classification tree.
  - Randomly restricted set of predictor variables to select from in each split.
- Detects contributions and behavior of predictor variables otherwise masked by competitors.

Random Forests

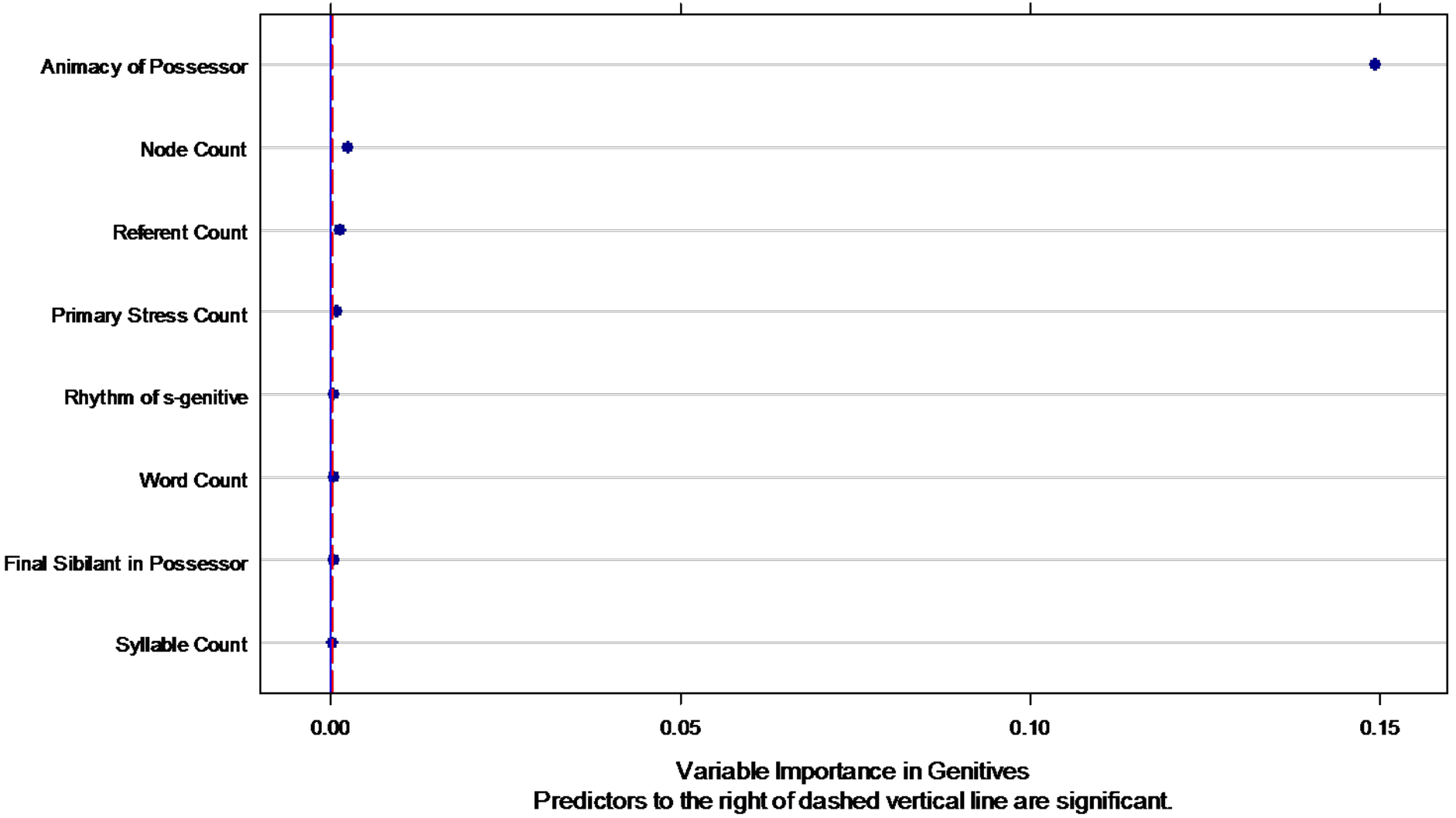
Conditional Variable Importance and Model Parameters

- Conditional Variable Importance
  - Permutation Accuracy: the difference in model accuracy before and after randomly permuting the values of a given independent variable, averaged over all trees in the forest. (Strobl et al. 2009b)
  - Ranks the importance of independent variables.

- Model parameters:
  - Genitives: `ntree` = 2000; `mtry` = 3
  - Datives: `ntree` = 8000; `mtry` = 3
- Model stability verified on two random seeds.

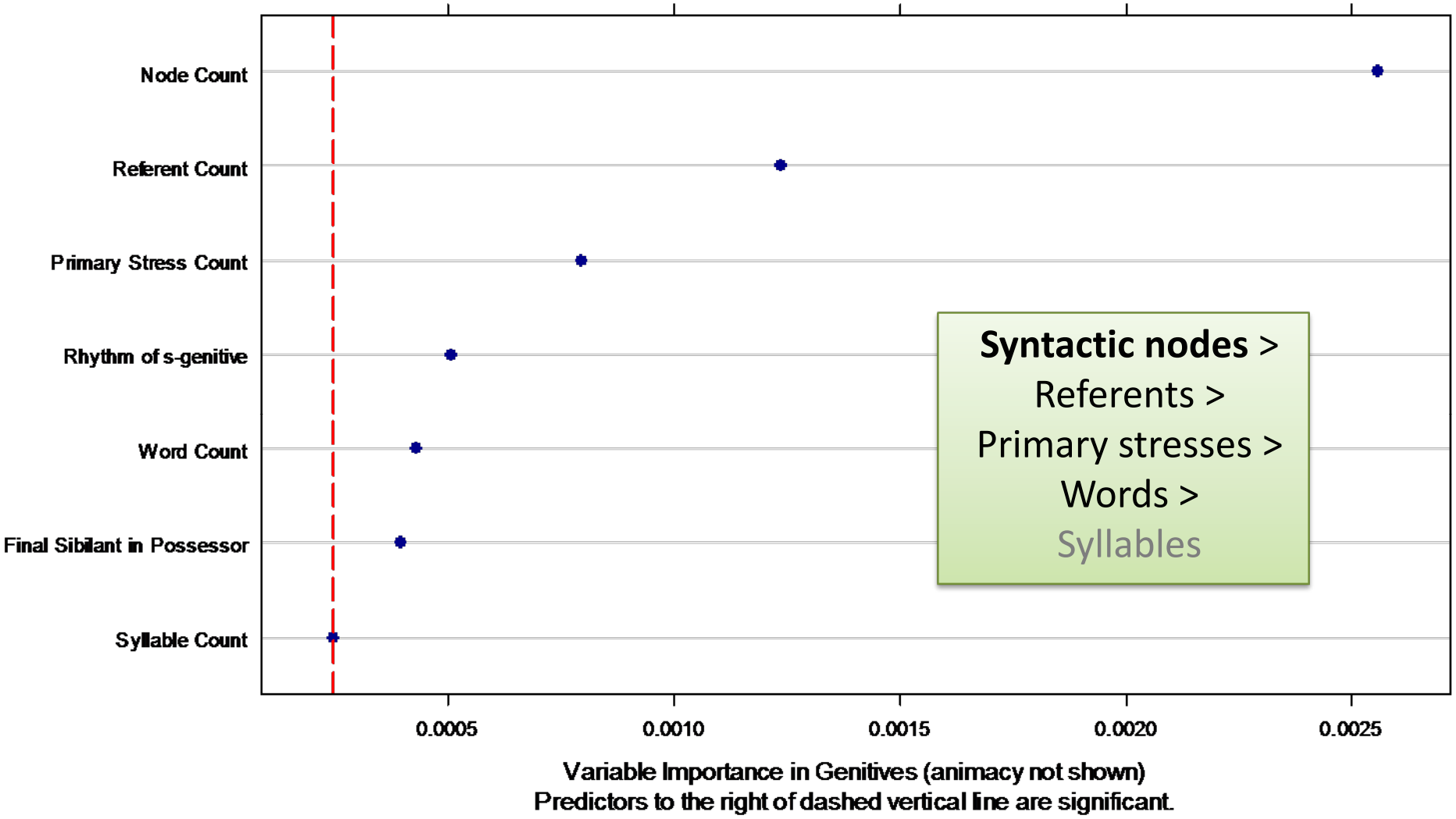
Genitives | Random Forests

Variable Importance



Genitives | Random Forests

Variable Importance

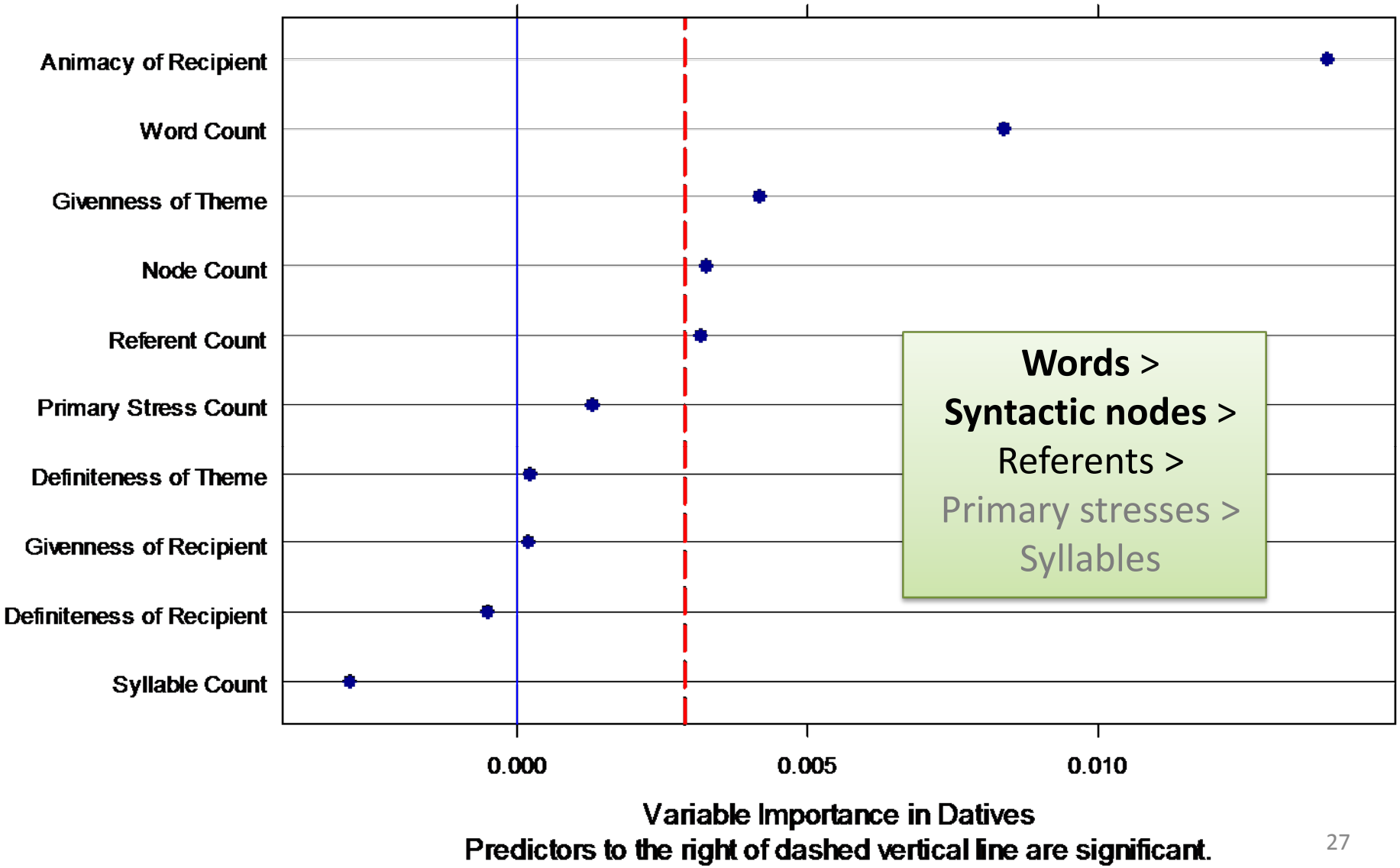


Genitives
AIC vs. Random Forests

	AIC	Random Forest
Genitives	**Syntactic nodes** > Words > Referents > Primary stresses > Syllables	**Syntactic nodes** > Referents > Primary stresses > Words > Syllables

Datives | Random Forests

Variable Importance



Summary
AIC vs. Random Forests

	AIC	Random Forest
Genitives	**Syntactic nodes** > Words > Referents > Primary stresses > Syllables	**Syntactic nodes** > Referents > Primary stresses > Words > Syllables
Datives	**Words** > **Syntactic nodes** > Primary stresses > Syllables> Referents	**Words** > **Syntactic nodes** > Referents > Primary stresses > Syllables

Discussion
Syntactic Complexity

- Number of syntactic nodes = best *individual* predictor of end weight in English genitive and dative construction choice.

- Is "weight" purely syntactic?
  - English binomial ordering studies: number of syllables affect ordering of nouns in binomial pairs. (Wright et al. 2005; cf., McDonald et al. 1993; Benor & Levy 2006)

- At a higher-level domain (i.e., genitives, datives), syntactic complexity is the most salient manifestation of "weight."

Discussion

Word count as a proxy

- Methodologically, the number of words—*though not perfect*—can act as a sufficient proxy for syntactic complexity and 'weight'.

- Dative construction choice:
  - Syntactic nodes and words are the best measures in comparison to the other measures tested.
- Genitive construction choice:
  - AIC: words are second best, though not great.
  - Random forest: not the most important measure

Discussion
Referents and DLT

- In comparison, referents are not the best measures of weight.
  - = Gibson (1998; 2000): Non-given and definite nouns and verbs

- What can contribute to integration costs? (Temperley 2006)

e.g., *the green ball*

Gibson:		x	= 1 new referent
alternatively:	x	x	= 2 new referents

➢ Redefinition of “referents” -> content words?

Discussion
Phonological complexity and weight

- Stresses and syllables rank low as good measures of weight for genitive and dative construction choice.

- Prosodic theory of end weight (=number of primary stresses) is not entirely syntax-independent.
  - phonological words ≈ content words

- Do possible phonetic correlates of weight or complexity play into end weight effects?
  - e.g., duration, complexity of segments, syllable weight or complexity of syllable structure (e.g., Benor & Levy 2006)

Future directions

Weight Beyond English

- How do measures of weight generalize beyond English?

- Is there a better proxy for cross-linguistic syntactic complexity?
  - Morphological complexity and weight?

Conclusion

- Two statistical methods resistant to collinearity:
  - AIC model comparison and selection
  - Random forest conditional variable importance
- Two alternations in spoken American English:
  - Genitives | Datives
- Tested syntactic, processing, and phonological measures of “weight.”
  - Syntactic nodes (syntactic complexity)
  - Referents (Dependency Locality Theory)
  - Words
  - Primary stresses (phonological complexity)
  - Syllables (phonological weight)

Conclusion

- Syntactic-based measures contribute most to weight-driven alternations in higher-level constituent ordering
  - (though perhaps heavily theory dependent)

- Methodologically, the number of words can be an appropriate and sufficient proxy for (syntactic) complexity and weight.

- “Weight” effects cannot be reduced to a single dimension.

Thank you!

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The authors' names are listed in reverse alphabetical order so as to satisfy the Principle of End Weight.

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Slides available online: http://stanford.edu/~stephsus/ShihGrafmillerLSA2011.pdf

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